

Congenital Heart Defects from Fetal Abdominal Electrocardiograph Signals using Signal and Image Processing Techniques

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ABSTRACT: Fetal heart abnormalities were the most common congenital anomalies and it caused the infant to have defects by birth. The fetal cardiac structure was small and due to fast movements the early diagnosis was too difficult. In this report the abnormalities were determined from fetal abdominal ECG. Initially pre processing was done to smoothen the waveform and for noise detection. This works based on adaptive filtering algorithm and other signal processing techniques. One of the inputs for this filter was coefficient of abdominal ECG. The correlations between the coefficients were computed using stationary wavelet algorithm and other comparing filtering techniques. Finally a peak detection algorithm was used to find the QRS peak position and the accuracy nearly about 97.663% of comparing with the standard filtering techniques.

KEYWORDS: Fetal abdominal ECG, Wavelet transform, QRS detection.

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INTRODUCTION

Congenital cardiovascular defects were structural problems that arise from abnormal formation of the heart or major blood vessels. About one baby in 100 has a heart defect in real time situations. The defect may be so slight that the baby appears healthy for many years after birth, or so severe that its life was in immediate danger.

It originated in the early stages of pregnancy when the heart was forming and they can affect any of the parts or functions of the heart functions. A fetal echocardiography was a method that does contain a detailed study of the baby's heart. The Fetal electrocardiogram (ECG) waveform analysis was done with the help of electrical activity of the fetal heart functions. It has given the required information about the physiological state of the fetus heart that can help clinicians works and to make appropriate and timely decisions during labor [1]. The fetal heart anomaly diagnosis depends on the expertise of the doctors and it's also time-consuming and takes delay decisions [2]. Thus induced for several emerging methods, were developed to assist the doctors.

Detection of heart activity and heart defects of a fetus using abdominal Electrocardiogram was [3] crucial. Compared to other technical and practical procedures used to assess the fetal health including CTG, electrocardiography (ECG) provides more power and useful information about the fetal heart conditions such as the FHR with a better predictive value.

Normally maternal abdominal signals were used to find Fetal ECG analysis and finding an optimum solution. A number of techniques have been proposed for fetal ECG extraction, such as adaptive filtering [4,5], blind source extraction (BSE) and combinations of some different algorithms have been taken into account. However each technique has its own limitations and advantages for the problem solving analysis.

Zhiheng et al. [6] have developed an approach, with the help of ICA and the theory of wavelet transforms, to find the Fetal Electrocardiograph signals for heart analysis and problem solving techniques. They used Wavelet transform at different and various stages of the algorithm to eliminate various kinds of noise.

Khalidon et al. [7] have described a new method for extracting the heart rate and the fetal heart rate variability (FHRV) signal, non-invasively using abdominal ECG recordings techniques for the problem solving applications. This technique was based on finding the fundamental frequency using Fourier transform method of signal processing approach. The Notch filters were used to suppress the noises in the signal which was received for the system analysis.

Al-Nashash [8] has reported the polynomial networks into the analyses of the fetal ECG signals for heart problem of fetal growth. Maryam Ahmadi [9] has developed an algorithm and added polynomial networks with the wavelet transform to find the structure of fetal Electro Cardio Graph (ECG) signals.

FETAL ELECTROCARDIOGRAM:

Figure 1 shows the typical ECG signal. This consists of three waveforms: P-wave [10], QRS-complex and T-wave[11] for the analysis. The amplitude and time delay were the two important information observed from the ECG waveforms. This value helps the doctor to find the fetal heart abnormalities in the early stages of the fetal growth.

The PR and PQ interval changes were used to find out the level of oxygenation. The Abnormalities of the ECG signals received from the heart leads to the brain injuries [12]. Hence the early diagnosis of heart helps the physicians to have an effective and appropriate intervention to save and precautions to be done for heart signals.

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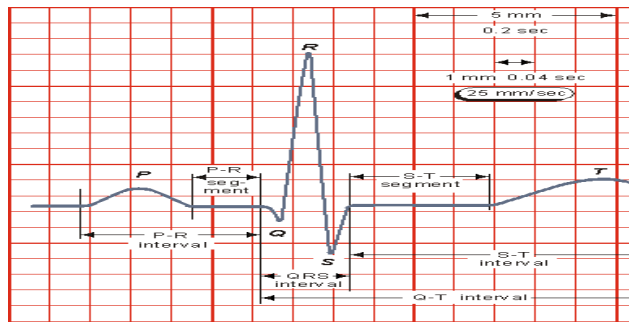


Figure1: Electrocardiograph signal

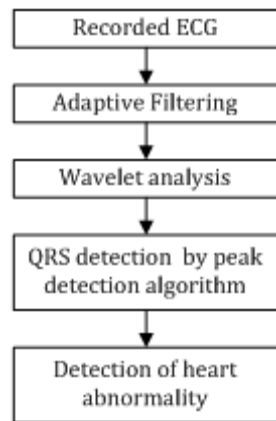
Proposed Algorithm:

Figure 2: Proposed method flow diagram

First, abdominal signals and thoracic signals were processed by wavelet transform, and the wavelet coefficients at each scale were obtained. For each scale, the detail coefficients were adaptive filtering algorithm.

As a classical algorithm, adaptive filtering has been used widely in fetal ECG extraction. The adaptive filtering configuration is shown in Figure 3

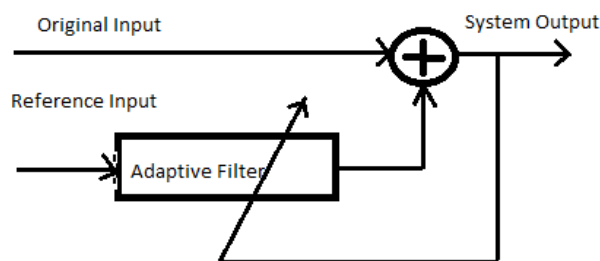


Figure 3: Structure of an adaptive filter

The adaptive filtering system has two inputs: an original input and a reference input. The abdominal signal was used as the original input $d(n)$, and the thoracic signal as the reference input $x(n)$. The coefficients of the adaptive filter were constantly adjusted with the feedback $e(n)$ until the output $y(n)$ was very close to the maternal ECG component of the abdominal signal. Then, fetal ECG was obtained by removing the maternal ECG component from the abdominal signal.

The adaptive filter was adapted by the least mean square error (LMS) algorithm, which is a most widely used adaptive filtering algorithm. The coefficients were updated based on

$$w(n+1) = w(n) + \mu x(n-\Delta) e(n) \quad (1)$$

where $w(n)$ is the adaptive filter coefficient, and μ is the chosen step size and Δ is the number of delay samples. When wavelet decomposition is performed progressively by the discrete wavelet transform (DWT), the length of the wavelet coefficients on each scale will become smaller. Thus, DWT is not time-invariant and is sensitive to small shifts in the input signal. These shifts can lead to major variations and may also produce signals of jump discontinuity after reconstruction. The jump discontinuity is called the Gibbs phenomenon. This problem can be avoided by removing down-sampling and up-sampling of the filter coefficients by a factor of $2j+1$ in the j^{th} scale in stationary wavelet transform (SWT). The output of each scale in SWT contains the same number of samples as the input. Because the length of the SWT coefficients at each scale is constant, SWT overcomes the lack of translation-invariance in DWT and can avoid the Gibbs phenomenon. Additionally, SWT can give a more approximate estimate of the continuous wavelet transform. In this paper, SWT was used.

The adaptive filtering technique based algorithm has a number of advantages over BSE and SVD, such as its transient and steady-state performance, computational simplicity in most situations, and good real-time capability.

RESULTS AND DISCUSSION:

To verify the feasibility of the proposed method, experiments were conducted using 30 cases of simulated data and 12 cases of clinical data. All the cases are the combinations of abdominal signals and thoracic signals.

Nine ECG signals were generated with the heart rate of 64, 76, 80, 84, 94, 120, 130, 140 and 154 beats per minute. The sampling frequency was 250 Hz, and the acquisition time was 30s. The ECG signals with the heart rate from 64 to 94 were used as maternal ECG, and the others as fetal ECG. The simulated fetal ECG amplitude is half of the maternal ECG. Figure 4 shows the three wave simulated maternal ECG, and the fetal ECG extracted. It can be observed that the proposed method reduces the noise effectively

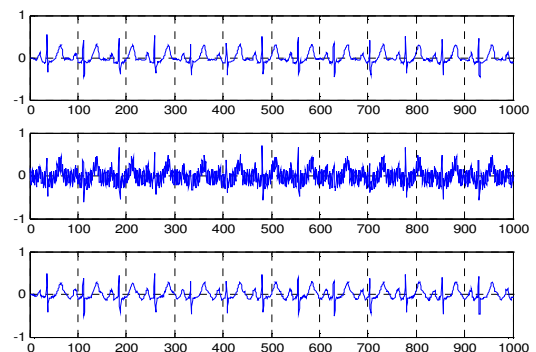


Figure 4: Adaptive filtered ECG waveform

The Magnitude and phase response of a adaptive filter was shown in figure 4. The frequency ranges were used from 0 Hz -500 Hz

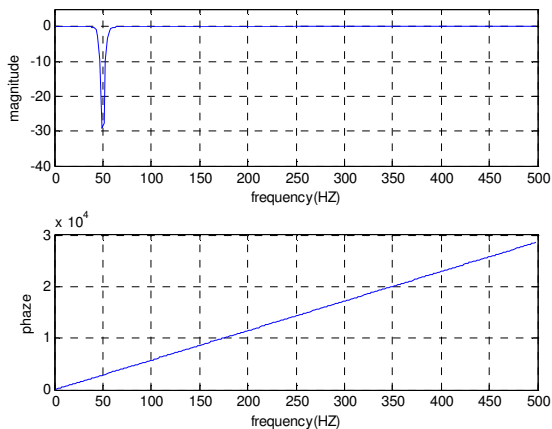


Figure 5: Magnitude and phase response

The simulated data with different heart rates were used to extract fetal ECG, and all of them can extract fetal ECG from the simulated abdominal signals.

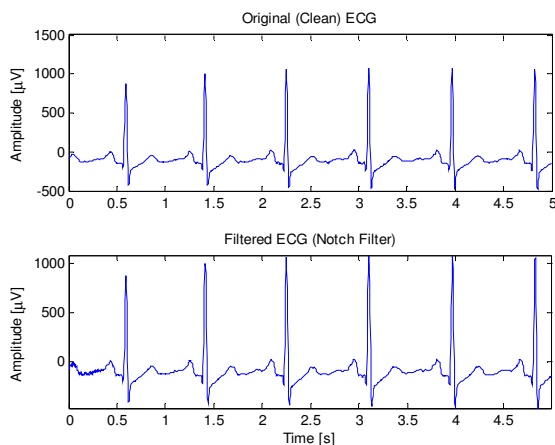


Figure 6: Filtered ECG signal

The detected QRS signal was shown in figure 7. The peak positions were determined using peak position detection algorithm.

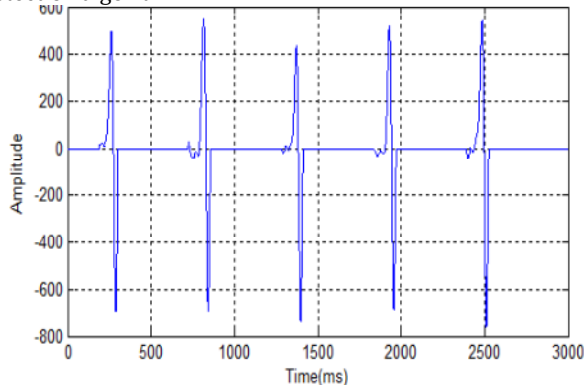


Figure 7: QRS peak detection

Fig 8 shows the comparison of the signal to noise ratio (SNR) based on eigenvalues (SNR-E) of the least mean square

(LMS) algorithm. It shows that the adaptive algorithm is still slightly larger than that of the LMS algorithm. The performances were compared 12 fetal ECG recordings

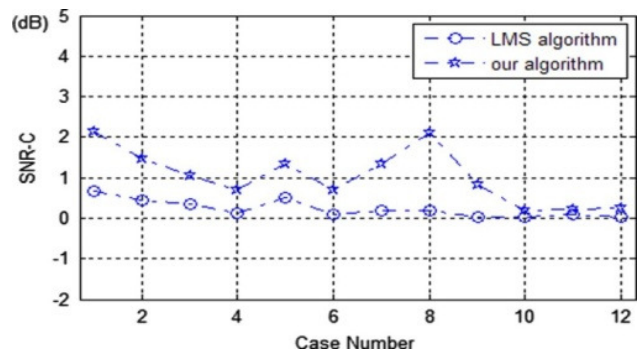


Figure 8: Comparison of the signal to noise ratio (SNR)

The main limitations of this work were that it has not been validated on pregnant women in the clinic. To verify its clinical feasibility, the proposed method must be tested clinically and improved correspondingly, and it seems that comparing the method with available commercial ECG systems is desired. Another limitation is that the current processing is off-line. These issues must be resolved to promote the method toward clinical application.

CONCLUSION:

A novel method for automatic fetal QRS detection has been proposed in this research proposal and analysed. The noise was eliminated and the extracted waveforms were more stable comparing to other signal processing techniques. It has been tested on 50 recorded abdominal signals which were received from the doctors who were working in their reputed hospitals with him knowledge. The performance and analysis of adaptive filtering technique based algorithm was compared using the LMS algorithm and the conclusion is the result of 97.663 of the practical based approach values. Future work can be done to find the abnormalities in the fetal image using the advanced soft computing techniques and the new technologies available in human body analysis.

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